problems; that, in fact, the most important and most difficult part of our undertaking consists in cultivating sound habits of thought and work, in developing breadth of interest and good judgment, in molding character, and in creating a high moral purpose.

ARTHUR A. NOYES

SOME PRINCIPLES IN LABORATORY CONSTRUCTION [1]

BY common consent, governing boards of colleges recognize that after a main building has been erected, the next should be a chemical laboratory. The artfulness of teachers of chemistry, perhaps aided by their fumes, has caused their colleagues to exhibit little regret and display but minor envy in the placing of the chemistry department under a separate roof. Limited funds and meager equipment caused the erection of the simplest structures at first. The stupendous development of our commercial prosperity and the more general appreciation of the importance of our science, not only in its applications, but as a factor in stimulating the dormant germ of culture in all men, have caused more generous provisions, with consequent elaboration in construction and equipment of chemical laboratories, entailing the most serious responsibility on the part of the professor in charge.

At the outset, I wish to make it plain that all the ideas put forward here have not been incorporated in our new laboratory. Many have. The reasons why the rest have not is of no interest to you. It is generally recognized that architects, however willing they may be, are of little real value in drawing up plans and specifications for laboratories beyond the exterior and artistic effects, as they are very special in their construction and use, of which the designer is naturally more or less ignorant. Our architect, Mr. George B. Post, however, has shown the greatest consideration and willingness to try to accomplish the ends aimed at. Much that I have to say is based upon a close study of laboratories in this country and in Europe. Many ideas we have put into effect have been secured here and there. A few are original.

The plan of a laboratory should be laid down in accordance with the destiny of the institution, as one may judge by its past and by a careful comparative study of the histories of other institutions, keeping in mind not only the immediate demands, but the probable developments within half a century.

LABORATORY PLAN AND ARCHITECTURAL EFFECTS

In the construction of chemical laboratories, different ideas have to prevail, depending entirely upon the immediate object aimed at by the laboratory. A private laboratory may be constructed along any particular lines desired. Undoubtedly a laboratory for the instruction of students in chemical engineering must be different from that used in instructing students of pharmacy or medicine. Most college laboratories, however, should be constructed with the object of giving a general training in chemistry, and not with the idea of training chemists. That should be incidental, which is not the case with technological institutions, where men are trained particularly in that line. Very special rooms, with particularly special apparatus, fixed and movable, must be provided, depending upon the requirements. This paper is concerned with laboratories for colleges in which general and not specific professional training is the aim.

While it is generally considered that a

[1] Read before the New York Section of the American Chemical Society, March 6, 1908.

chemical laboratory is a workshop, nevertheless a bit of decoration without and within can not fail to gratify the artistic. This is particularly true when a laboratory forms one of a group of buildings constructed according to a particular architectural plan. To cause the chemical laboratory of the College of the City of New York to conform to the architectural features of the rest of the buildings, there have been placed four shields of terra-cotta, about two meters high and one and a half meters wide, on the ends of the building. The two shields in front of the building have two series of alchemistical symbols, indicating the two fields of organic and inorganic chemistry. The other four have the alchemistical symbols indicating the old elements of earth, air, fire and water.

The ground plan of a laboratory should be laid out to secure the greatest amount of light, air and compactness. The plot of land will, of course, influence any decision. Where land is available, it is generally considered by those who have had experience that a building in the shape of the letter E is most satisfactory. The main entrance may well be placed at the front of the central extension, which, being two stories above the basement, may provide space for the main lecture theater. This part of the basement may well be arranged for receiving freight and contain the main or central room for stores.

It is desirable to limit the entrances to the building to two. Near the main entrance should be the director's office and just within this main door should be a small office for the janitor or door-keeper. All communications should enter the laboratory of the building by that means, and the other entrance to the laboratory should be at the rear, or within a court if the building is constructed with a court, and in connection with the main storeroom. This entrance should be used solely for freight purposes.

The width of the building, in my opinion, should at no point be more than sixty feet, except where the lecture theater is located. This will provide an ample corridor of about ten feet and laboratories not too deep for good light throughout, from without. To secure the latter, ceilings should be at least fifteen feet in the clear from the floor. By the use of reinforced concrete for the interior construction, the greatest economy in height of the building may be had.

FLOORING

There has been very much difference of opinion in regard to the kind of material of which to construct flooring for laboratories. Cement is hard; wood gets soggy and is affected by chemicals that are spilled; and asphalt compositions get soft. The heavy desks and hood supports sink and the furniture is thrown out of plumb. A number of different materials have been suggested. In my opinion the best which has been put forward is that which is known as lithoplast, devised by Dr. W. L. Dudley, of Vanderbilt University. It is essentially a paraffined sawdust sand floor, with a magnesia cement. This flooring may be laid in any length and in one piece, and offers many desirable qualities. The baseboard may be made as a part of this floor. There are no cracks. The presence of the sawdust allows of its expansion and contraction with changes of temperature, and the coating of paraffine over it prevents its rotting or napping, which are the objections put forward in opposition to composition floors containing sawdust. It may be tinted, polished, washed or scrubbed. It can be repaired without having cracked joints, and, furthermore, it allows nails and screws to be driven into it in much the same way that wood does.

PLUMBING

It is well recognized now that the plumbing in a laboratory should be exposed. This is accomplished in some cases by having a pipe trough in the floor, covered by a removable trap or grating. This is unsatisfactory, as such a conduit constitutes an open sewer in the floor.

The piping can be best suspended from the ceiling. This need not be in a haphazard manner, presenting an unsightly appearance, but the pipes may be carried in such order as to really constitute a decorative feature of the rooms. In carrying piping from floor to floor, they may be placed in a cupboard in the wall. The face of the cupboards, being held in place by screws, will give ready access in case there be need to inspect or make repairs.

It is advisable to insert a valve in the main which leads to each laboratory. By this means, in case there is need for repair in any one particular laboratory, only that laboratory is thrown out of commission for the time.

As the result of very careful study of the matter of the composition of the waste-pipe, I will say that I regard a high carbon cast iron as being the most satisfactory. This should be dipped in heavy tar which has been heated until it is perfectly fluid. These drains, with a suitable dip and trap, lead to vertical chemical wastes. The latter may well be of glazed earthenware joined with hot tar and surrounded by six inches of concrete. By having several trunk lines, vertical and opening out through the roof, there is little danger of clogging, and corrosion is reduced to a minimum. Obstructions may be removed by dropping a weight, suspended by a cord, through the opening above the roof.

The form of sink connecting with these wastes is not a mere matter of taste. Alberene serves the purpose admirably, but where it is possible, I think the porcelain overflow roll-rim flush sinks should be used. A perforated outlet prevents large solids being washed into the system. A rubber disk, or even a piece of paper, placed over the perforations gives a pneumatic trough of constant level. Should concentrated acid or alkali by chance come into the sink, it may be instantly diluted by turning a valve.

PAINTING

Undoubtedly whitewashed brick walls constitute a very satisfactory finish for a laboratory. White plaster is more attractive, and still more satisfactory is the white plaster which has been given three coats of acid sulphur-proof paint. A combination lithophone and zinc oxide has proved eminently satisfactory. Incidentally it may be stated that a number of paints were tested and found wanting.

All metal ware, which is likely to be exposed to any fumes whatever in the laboratory, should be painted with an acid-proof paint, and that which is underneath the hoods or between the desks may be treated with a black damp-resisting paint. All pipes upon the ceiling, etc., may be covered with the white enamel acid sulphur-proof paint referred to above.

VENTILATION

There are various systems for ventilating buildings in vogue. The one settled upon by our ventilation expert is known as the push and pull system. The air is filtered, drawn over tempering coils by a large motor-driven fan, carried by ducts, and driven in at the upper portion of the room. A fan in the attic pulls the air from the bottom of the rooms through corresponding ducts. Some prefer the pressure system, arguing that the tendency of the air to leak in around the windows is avoided, and,

furthermore, that it facilitates the operation of the hood vents. The hood vents should, in my opinion, be joined up in a separate system with a separate fan. This fan located in the attic will draw the air out at a pressure of about three times as strong as that of the ordinary ventilating system. By providing slides for the hood outlets, or so-called chemical vents, economy in the speed of the motor may be brought about.

Undoubtedly glazed tile is the best material of which to construct the chemical vents. These should be set in hot tar. With buildings constructed of steel and stone, it is not easy, where sizes of the vents are variable, to secure a material properly burned, and it is difficult to hold it in place. We therefore devised a lining for our ducts which we think is satisfactory. The ducts may be cut to pass obstructing steel members or to follow any line that is desired. These ducts are essentially a frame of galvanized iron on the inside of which a lattice work of expanded metal is riveted. Upon this is placed from five eighths to three fourths of an inch of a cement containing some plaster and a sodium silicate composition, which sets to a very rigid mass. It is acted upon very slightly by acids. Of course, hydrofluoric acid attacks it as it does glazed tiling. This is subsequently covered, after thoroughly drying out, with three coats of an acid-proof paint. That which we used was devised by Mr. Maximilian Toch. It may not be uninteresting to give an account of some of the tests to which a preliminary sample duct was subjected before the instructions were given to proceed. A joint was made and was placed in contact with concentrated sodium hydroxide, concentrated ammonium hydroxide, and concentrated hydrochloric, sulphuric and nitric acids. It was slightly affected by the concentrated nitric acid. The coating was furthermore subjected to the vapors of boiling sulphuric acid and to a stream of chlorine. We felt that if it would withstand these reagents it could be safely placed in the building. The interior of these flues may be repainted from time to time by closing all the vents on any one line of the system, except the last one. Atomized acid-proof paint may be swept through the system by having the fan going at full speed. The large duct, five feet in diameter, at the end of the system, should be arranged to collect condensed moisture in a trough from which it may flow into the chemical drain. A man-hole placed at this point allows a cleaner to enter and wash down the walls by means of a hose.

HOODS

The hoods, preferably constructed of wood, should have a stone base slightly inclined to the rear, where an outlet is provided to the chemical drain. We have found that a cup cast of lead containing nine per cent. of antimony is most satisfactory for a connection to the cast-iron chemical drain to which reference has been made. Muthmann has constructed the drain pipes in the new Munich laboratory of this alloy. It is somewhat expensive, but exceedingly attractive, to have the rear of the hoods faced with glass tiling, and the vents made of white porcelain. But if they can do it in Childs's restaurants, I thought we could. Each hood is provided with two vents, one about twelve inches from the floor of the hood, and the other about twelve inches from the top. These vents are provided with sliding porcelain doors so that they may be closed when not in use.

HYDROGEN SULPHIDE

Hydrogen sulphide is delivered throughout the laboratory from a central generating plant in the basement. The Parsons

generator, installed in duplicate, and constructed upon such unusually large dimensions that each apparatus will supply two hundred and fifty outlets operating simultaneously, has been adopted. In this connection the opinion is advanced that the setting aside of a special room where students congregate from all over the building for the use of hydrogen sulphide is unnecessary, and inviting the degeneration of liberty into license. In other words, the "stink room," for large laboratories at least, is a relic of the past. A shelf placed out of doors, in a court, for example, may be provided for the limited number of students, who from time to time must use large quantities of such gases as chlorine.

Lead-lined iron pipe is used for the transporting of hydrogen sulphide and hard rubber cocks are attached to this on the interior of the hoods. No hydrogen sulphide outlets are had except in the hoods. The front windows of the hoods are suspended upon paraffined window cord, which I think is superior to the bronze tape or chains used in some laboratories.

All outlets, except those mentioned, are brought to the front and underneath the floor of the hood. Just within the line of the base of the window-case are bored holes through which the tubing can be led into the hoods. When the tubing is not in all of these holes, the hood is thoroughly ventilated, when closed, by means of these openings.

DISTILLED WATER

The problem of economically providing ample distilled water for a large laboratory is one requiring most careful consideration. It has long been known that condensed boiler steam, even with oil arrestors, fails to be pure enough even for ordinary laboratory work. After securing much advice, the system here outlined was adopted. It may be constructed of any number of units. The water is preheated to remove free ammonia. We have the evaporators in duplicate and twenty condensers. On the try-out, three hundred gallons were produced in an hour. The apparatus is erected in the attic. The principle upon which it depends is that of boiling water with high-pressure steam passing through coils within the evaporators. The evaporators are thirty-nine inches in height and thirty inches in diameter, outside measurement, and contain one hundred and forty feet of extra heavy drawn copper tubing, properly coiled and coated with the best quality of block tin. The outer shell is of fifty-ounce cold-rolled copper; the heads are of same weight and are securely fastened to the sides with three-eighth-inch steel machine bolts. All spuds, nipples and fittings and all inside surfaces coming in contact in any way with the water, are heavily coated with the best quality of pure block tin; all joints are of invisible silver brazings, and all the fittings were sweated and brazed.

The evaporators are fitted with water gauges and cocks, all necessary steam, water and sewer connections, and suitable hand-holes for cleaning. The condensers are six feet in height, composed of two cylinders, the inner cylinder being seven inches in diameter, and the outer cylinder eight inches in diameter. The inside tubes are constructed of twenty-ounce cold-rolled copper, and the outer tubes of twenty-four-ounce cold-rolled copper, block tin coated inside and out, lap seamed. All joints were sweated and soldered with pure block tin. All fittings for water and steam connections are tacked together at regular intervals to prevent buckling with brass blocks, block tin coated. The bottoms of the condensers rest upon and empty directly into a large tin-lined reservoir. Tin-lined iron pipes with tin-lined valves serve

to distribute the water by gravity throughout the building.

OXYGEN AND HYDROGEN

Hoods in which hydrofluoric acid is to be generated, or silica is to be driven off by that acid, should be lined with thin sheet lead. The front windows may be paraffined.

Oxygen and hydrogen can now be conveniently produced electrolytically in suitably placed tanks in which the gases are collected as generated, and stored. Both of these gases can be laid on to the lecture table and in the spectroscopic room. It is also desirable to have the oxygen laid on to the combustion room adjoining the organic laboratory. In this connection it may be stated that a good safety device is necessary to prevent back flash and possible explosions in these pipes. This can be readily accomplished by inserting a device built on the principle of the Davy lamp. About a meter from the final outlet the pipe is increased to double its bore for 250 cm. and then reduced again to its normal size. By inserting a loose roll of copper gauze in this enlarged portion of the pipe the striking back of the flame is avoided.

LECTURE THEATER

The lecture theater should be lighted by skylight and provided with a horizontal black curtain, electrically operated, for darkening the room. On dingy days or in the evenings, this room should be illuminated by diffused light from overhead reflection of electric bulbs hidden along the cornices of the room. If chandelier lighting be used, the Zalinski diffusion reflector made by the Halophane Company should be installed, as the best results are obtained from them.

The esthetic sense has been appealed to in our lecture room and museum by placing in each of these large rooms four plaster cornices. In the lecture room the four give a mythical representation of the realms of solid, liquid, gaseous and unknown forms of matter. In the museum we have the unknown of the past typified, the period of alchemy, the period of chemistry, and the celestial. A magnificent mural painting pleases the eye of one who sits in the grand lecture theater at the Sorbonne in Paris. In our theater, one looks not at the blank walls, but on the left-hand side he sees a framework which carries the names of the accepted chemical elements and the international atomic weights on movable panels. In this manner, as new elements are discovered, the panels may be shifted. As the atomic weights are changed as the result of our increased knowledge and more accurate work, the values can be changed. It may be interesting to call your attention to the fact that provision has not been made for more than one hundred elements, although I am aware that three hundred or more have been suggested.

On the right side of the wall we have the periodic arrangement of the elements in panels. Immediately underneath these panels are chart hangers, ammeters and voltmeters thirty-six inches in diameter (with illuminated scales) for both alternating and direct currents for electric furnace and other demonstrations. Immediately underneath these are glass blackboards with marked squares, the lines of which are not plainly visible at a distance in the room itself, but may be used with ease by the lecturer in plotting curves.

A suitable and separate system of illumination for the blackboards should be provided.

In my opinion, a lecture room should not be constructed to seat more than 250. The size of the room is so great when a larger number is taken care of that those sitting

at the rear, however elevated the seats may be, have difficulty in seeing what actually takes place upon the lecture table. Should the lecture room be larger than that referred to, the experiments must be performed on a very large scale. This we have, in a measure, obviated by placing a reflectoscope on the lecture table, with which experiments on a small scale may be performed, and then thrown upon a screen overhead. In order to accomplish this, the instrument projects various objects upon a mirror which reflects it upon the screen. The screen can be operated to change its angle so that distortion is prevented, as is the practise at Cornell.

In addition to the projection lantern operated on the lecture table, to which reference has been made, a double dissolving lantern is placed at the rear of the room. A convenient method for signaling the operator is had by means of white and red lights, duplicates of which are placed within the movable reading desk on the lecture table so that the operator may signal the lecturer in case there is some temporary delay. Some people prefer a transparent screen placed behind the lecturer with the lantern operated in a room to the rear. We have provided one for such experiments that utilizes the sunlight, which may readily be reflected by a heliostat properly supported without a southern window.

LECTURE TABLE

Many lecture rooms have the lecture tables convex, which, in my opinion, is wrong. Those sitting at the extreme right, for example, see the apparatus head on and can not observe what is really going on. If the table be concave, this is obviated. I do not know any lecture theater in which this system has been adopted. As a matter of economy in room, the straight lecture table perhaps gives the best results.

It will be recognized that the experiments for demonstration should be selected, if possible, from those which show color changes or changes in volume, rather than weight. Pneumatic troughs with glass front and back and rear illumination have given satisfaction in many laboratories. In addition to these we have incorporated a pneumatic trough with mercury, so constructed with an extension pipe 5 cm. in diameter and 800 cm. long, that eudiometer tubes, 2 cm. in diameter, may be raised or lowered to secure an increased or diminished pressure of one atmosphere. The convenience of such an arrangement is obvious.

The size of the lecture table is a matter requiring grave consideration. Some of the most distinguished American lecturers in chemistry think that experiments should be selected to show but one thing at a time. This can not always be done, but necessary apparatus for the experiment, as gas scrubbers, for example, may just as well be placed out of sight and that part of the installation to which the attention of the student is to be particularly directed placed on the table. Despite the clarity of explanation, students often give attention to a fluid flowing into an aspirator bottle, for example, instead of observing the change of color in copper oxide which may be heated in an atmosphere of hydrogen. This principle is so emphasized by some of our most experienced and expert teachers that they allow the apparatus for but one experiment to be placed on the table at a time. That must be removed before the second is begun. An elaborate array of apparatus upon a long table is undoubtedly theatrical in effect and may serve to catch the student's attention at once and hold it throughout the discourse, as he will be afraid of missing a trick. This is not to be depended upon, however, for the next lecture, perhaps upon a more important topic

of even greater interest, requiring but little apparatus, may serve to place the student in the opposite frame of mind.

The earnestness of a lecturer frequently urges him to come close to his hearers. It is remarkable what a difference is produced in that intimate mental association between teacher and student when the broad barrier of the lecture table no longer separates them. If the table be long, the psychological moment often passes in the extended march to get around the end of the table, or the time consumed in retracing one's steps wastes the opportunity to briskly emphasize by a quick reference to a sharp experiment. The desirable features of the various methods referred to may be attained by having a long table, say ten meters in length, so constructed that the two meters of the center are movable, being placed upon ball-bearing rubber-tired wheels. Certain experiments involving distillations, etc., may be in place upon either of the fixed partitions. The center may be removed, giving free movement in and out for the lecturer. By having several of these sections, experiments requiring apparatus which must be built up each time, as for example, some forms of electric furnace, may be performed and temporarily removed without disturbance. One of the movable tables may well be provided with a slab of soapstone or slate.

On the lecture table waste outlets for condenser water may be provided, as well as electric outlets for storage battery (low pressure), direct and alternating currents, switches for the several lighting systems, lantern operators, motors controlling the darkening shades, and numerous cocks for gas, water (cold and hot), steam, compressed air, vacuum, oxygen, hydrogen and hydrogen sulphide. Down-draft vents should be provided in each of the fixed portions of the table. An explosion shield of plate glass is easily lowered into the front of one or both of these tables. By a system of sliding doors, all cocks, drawers, etc., may be closed and locked by one key, thus making a complete cabinet.

Underneath and within sight of the lecturer there should be a clock attached to the electric system of the building. In this connection I should like to say that I think a wall clock visible to the students has no place in the lecture room, or, if it be there, it should be in operation only upon public occasions. In the lecture room the student should give undivided attention to the lecturer and the speaker should be the one to keep an eye upon the time. In the laboratory, there should be a clock within clear sight of every student, as he frequently must regulate the speed of his work by the time at his disposal.

PREPARATION ROOM

The preparation room should be placed preferably at the rear of the lecture desk, although in many laboratories it occupies the space underneath the elevated seats at the rear of the lecture room. A convenient arrangement is to have the preparation room and museum adjoining. In the preparation room it is desirable to have a thoroughly equipped chemical table. A hood should be placed in this room for the convenience of the lecture assistant that he may pursue a research. As he usually gives almost all his time to the preparation of lectures, he should be located right at his work. It is desirable to have in the preparation room, lathes for both metal and wood, an anvil, a large vise, and a carpenter's bench, in addition to the glazed cupboards for storing apparatus used for lecture purposes. There should be a drawing table, also.

In the stock room adjoining the preparation room there should be an annunciator in connection with each laboratory throughout the building and the director's office.

ARRANGEMENT OF ROOMS

It is desirable to arrange the laboratory so that the instruction of a particular kind is done on one floor, as far as possible, or in suites of rooms suitably arranged. We have found it convenient to place the laboratories for general chemistry upon two floors, two of them on the floor adjoining the lecture theater, and four on the floor immediately above. In this manner the presence of a large number of students in the corridors of the remaining portions of the building is avoided. In a college, of necessity, the main instruction is with the first-year students.

Where much demonstration is to be done in the laboratory, it is desirable to have all of the desks in the laboratory facing in one direction, the instructor having a desk upon an elevated stand. This is expensive in room consumption, however. Each desk at least should have a sliding shelf for the student's note-book.

Between each pair of laboratories at the end of the corridor is placed a quiz, or recitation, room. This recitation room will seat the largest number of students which can work in any one laboratory at a time. The principle involved is that essentially outlined in the first paper of this series. The lecture room is for the presentation of general principles, and illustration and elaboration of those principles. This can be done with a large body as well as with a small body of students. When, however, a student must apply some of these principles himself, we regard it wiser to have only a limited number of students working in a laboratory at a time. They are, therefore, divided up into sections, never having a larger number than twenty-eight, and preferably less.

On the third floor from the top, the second-year students may work in analytical chemistry. In addition to four analytical laboratories on this floor, we have an organic laboratory. The organic laboratory has connecting with it a room in which extra precautions have been taken to make it fireproof. This room is used as the bomb room. Opening into the organic laboratory is the combustion room, provided with two tables, fitted with two furnaces each. Suspended above each table is a metallic hood, painted with acid-proof paint, for ventilation purposes. These hoods are connected, however, with the chemical vents, as we get a stronger pull from that fan. On passing through the combustion room, we enter the small balance room, thence back into the organic laboratory.

BALANCE ROOMS

The balance rooms, numbering ten in our building, are arranged without regard to illumination by means of sunlight. We depend entirely upon artificial illumination. In this manner we save much lighting space which is frequently sacrificed for the balance rooms. Furthermore, it has distinctive advantages, because the shadow cast by artificial light is a constant and fixed one, whereas it varies with sunlight, depending upon the time of the day.

Our curriculum requirements lay down as prerequisites for physical, organic, industrial, advanced analytical chemistry, or metallurgy, courses not only in general, but qualitative and quantitative analysis. It will thus be seen that the second-year students all work on one floor. A few third-year students work on the same floor in the organic laboratory. The other third-year students and the senior class work on the ground floor, where we have a suite of rooms for physical chemistry, consisting of a laboratory for physical chemistry, an electrolytic and electric furnace room, and a spectroscopic analysis room. The students who may have elected applied chemistry work in the laboratory bearing that name, and just across the

hall there are three laboratories adjoining one another for water, bacteriological and gas analysis. In the gas analysis room we have found it satisfactory to build the floor of asbestolith composition, which does not crack, so arranged that the baseboard and floor are all one piece and slope slightly to a central cup for the collection of mercury which may fall upon the floor. In the gas analysis room we have also a tin-lined tank holding 100 liters of distilled water, so that gas measurements are made with distilled water of the same temperature as the room.

The advanced analytical laboratory is provided with drying ovens, like those in the Massachusetts Institute of Technology, steam baths, such as one sees in the Harvard laboratory, closed and open hoods. These are constructed of glazed brick, set in cement and pointed up with plaster of Paris. The steam baths are constructed of alberene covered with a series of porcelain rings and are placed opposite plugged vents. Constant water-level contrivances are connected. The water is heated by means of high-pressure steam. In the basement we have a small room adjoining the assay room, which contains grinding machinery, pulverizing and bullion mills, and also types of furnaces, such as wind, down-draft gas, muffle and annealing furnaces.

Except in the case of the laboratories for general chemistry, there is a private laboratory for an instructor adjoining each laboratory in which the students are supposed to pursue a particular course.

In the basement we have a machinery room, containing two filtering plants, a drum for heating water, compressed-air engines, and water and vacuum pumps. In the line of the vacuum piping there is inserted, just before it reaches the pump, a scrubbing apparatus built of cast iron, lined with porcelain. Three of these drums are arranged so that the gases which pass into the vacuum pump are passed through a tower of pumice saturated with concentrated sulphuric acid; another tower containing solid caustic and the third one is placed in front as a safety reservoir. These towers are so arranged that they may be cut out of the system for a short time so they may be cleaned and refilled. This is done from the top. The accumulated liquors may be drawn from the bottom by means of hard rubber cocks.

One small room having a floor drain and connection with the chemical vent is set aside in the basement for the hydrogen sulphide generators. The floors, walls and ceilings are of one piece of asbestolith. This practise is followed in the storage battery room on the same floor.

A constant temperature room is conveniently had by selecting a small inside room in the center of the building and next the ground. It may be lighted by electricity, and, in this way, comparatively slight changes of temperature will be observed during the year.

STORAGE BATTERY

The principle advocated for storage-battery control may best be explained by outlining our system. Forty-eight cells are provided, with a discharge rate of 60 amperes in one hour, and with 120 ampere hours capacity on an 8-hour discharge. The cells are permanently connected as follows: One battery of 8 cells, connected two in series and four in parallel, giving four volts and capable of discharging at the rate of 60 amperes for 8 hours; two batteries of 12 cells each, connected three in series and four in parallel, giving 6 volts and having the same discharging capacity as the 4-volt battery; one battery of 16 cells connected four in series and four in parallel, giving 8 volts and yielding 60 amperes for 8 hours. All the batteries can

be discharged so as to give 240 amperes in one hour.

The four battery systems are connected by cables to five bus bars on the distributing board in the electrolytic room, each bar being provided with 24 distributing sockets. The ends of the batteries are connected in series so that the differences of potential between the bars are, respectively, 4, 6, 6 and 8 volts, and 24 volts between the end bars. By this arrangement any desired voltage from 4 to 24 volts may be obtained. Connections are made from the distributing sockets to any current outlet in any part of the laboratory by means of plugs connected by a flexible cable provided with a fuse. Current is supplied to the user at the voltage and maximum current strength asked for. It is possible to supply about 60 outlets at a time with any voltage up to 24 volts. On disconnecting any allotted cells, the user has to state the approximate number of ampere hours taken from them. A record is kept of this for each battery, and it is thus easy to tell when a battery requires charging. The cells in each battery being used up at the same rate, any single cell is protected from being run down by a careless user, and all cells in a battery are in a comparable state.

The charging leads from the dynamo are led direct to the electrolytic room and connected to two sockets, and the charging connection to any set of cells is made on the distributing board, the battery room only having to be entered to inspect the cells. Current can also be taken direct from the dynamo from these sockets. Two plugs on the distributing board are connected to traveling cables in the battery room, so that any desired number of cells can be permanently assigned for specific purposes, and the condition of each cell investigated. The switchboard is of the simplest construction, yet it offers the most flexible arrangement known to the writer. It is essentially a marble slab supported vertically with brass-lined equidistant holes. A pair of holes leads to each outlet in the laboratory and is numbered. At the bottom are five rows of similar holes leading to the sets of cells in the battery room referred to. The connections are made by two flexible cables.

ELECTRO-ANALYSIS

Knowing of no better arrangement, the room for electro-analysis was copied after that of Professor Edgar F. Smith, of the University of Pennsylvania. There are 14 places containing voltmeters of 50 volts in half-volt divisions, and four voltmeters of 150 volts in half-volt divisions. On each side of these are two ammeters, one reading from 0 to 1 ampere in 100 ampere divisions and the other from 0 to 25 amperes in one fifth ampere divisions. The rheostats for these instruments are of the enamel type, having a total resistance of 172 ohms and divided into 51 steps arranged in geometrical progression.

STOREROOMS

The arrangement of the stock rooms presents interesting problems which are met, as a rule, in many small stores where compactness affords limited opportunity for roominess. As many drawers of various sizes, for different purposes as can be, should be built as part of the cabinet work up to about forty inches from the floor. Upon this can be constructed two kinds of shelves. First, ordinary wooden bottom shelves, preferably movable, for holding chemicals in bottles; second, wire-bottom shelves for holding glassware. Glass tubing and rods, placed on end, are well taken care of by upright partitions about 15 cm. apart and 25 cm. deep. It is desirable to have suspended over the outside of the last men-

tioned, for at least half the distance down, a cloth which prevents the accumulation of dust within the glass tubing. The value of glass for blowing purposes is frequently destroyed by minute particles of dust which accumulate inside the tubes.

In each stock room there should be a large chemical sink, either of alberene or porcelain, preferably the latter, provided with a flush rim. This sink is equipped with cold, hot, and distilled water. Above the sink, peg boards should be placed for the draining of glassware. It is desirable to provide non-spattering nozzles for the cocks over these large sinks.

As alcohol is bought in quantity and without the internal revenue tax, it is necessary to keep careful control over it. We have accomplished this in a most satisfactory manner by securing one of the copper tanks made by the Bramhall, Deane Company. The tank is so constructed, that alcohol is readily pumped into it from the regular containers in which it is shipped. It is provided with a safety valve to prevent excessive pressure being created in case of its being accidentally heated. It is also provided with a glass gauge the entire height, so that the contents may be judged. The cock by which the alcohol is drawn off is made with a lock.

It will be observed from the above that the teaching of one kind of chemistry is localized, and, as one progressively descends, the work of the student becomes more and more specialized along lines of preparatory study which he is to pursue subsequently at a professional school.

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THE AMERICAN BISON SOCIETY

The president of the society, Dr. William T. Hornaday, has written a letter asking cooperation with the society, in the effort it is now making to complete a fund of $10,000 with which to purchase and establish the Montana National Bison Herd, on the range that has been provided by congress. The ultimate object of this movement is to perpetuate the Bison species and leave it for future generations of Americans. It is hoped that there may be at Ravalli, Montana, in the not far-distant future, a herd of a thousand pure-bred bison, owned by the national government, and self-sustaining, on a fenced range.

At its last session, congress appropriated $40,000 with which to buy from the Flathead Indians twenty square miles of choice grazing grounds, erect a fence around it and dedicate it to use as a national bison range. The society pledged itself to provide the nucleus herd, and present it to the government, as soon as the range is ready. Ten thousand dollars must be obtained with which to discharge this obligation. Up to date subscriptions amounting to $3,102 have been received, and subscriptions to complete the amount required should be sent without delay to Dr. Hornaday, at the Zoological Park, New York City.

THE COMMITTEE OF ONE HUNDRED OF THE AMERICAN ASSOCIATION ON NATIONAL HEALTH

The president of the committee, Professor Irving Fisher, states that President Roosevelt has definitely taken up the program of the committee as part of his administration policy. He intends to incorporate the recommendation in his next message to congress—that the health bureaus of the government be concentrated into a common department, from which the bureaus not consistent with health and education will be removed elsewhere. This will be the first and most important step toward a powerful department whose special interest will be health and education.

The president authorized the announcement of this decision at the recent conference in Washington between the Committee of One Hundred, the American Medical Association, the American Public Health Association, the Conference of State and Provincial Boards of Health, the National Child Labor Committee, the Government Commission on the Organization of Scientific Work, the Public Health and